DOCUMENT RESUME

ED 047 330 95 SE 008 761

AUTHOR Glaser, Robert
TITLE The Psychology of Learning and Instructional Technology.
INSTITUTION Pittsburgh Univ., Pa. Learning Research and Development Center.
SPONS AGENCY National Center for Educational Research and Development (DHEW/OE), Washington, D.C.
REPORT NO 42-60
PUB DATE 70
NOTE 19p.

EDRS PRICE EDRS Price MF-$0.65 HC-$3.29
DESCRIPTORS Behavior, Educational History, *Educational Psychology, *Educational Technology, *Essays, Instructional Technology, Learning, Learning Theories, Literature Reviews, Psychological Design Needs, Teaching Models

ABSTRACT

(1) What is learned in a particular subject matter? (2) How is learning? (3) How does competence develop? (4) And how is learning assessed and optimized? These are the questions asked and answered in this essay. (5) The relationships between units of learning establish the subject matter structures that are learned; e.g., concepts, rules, principles, and strategies. Specific properties of letters, pictures, numbers, and sounds comprise the units and structures in the learning of young children. (2) Traditionally, measurement and diagnosis of students followed a "selection model." This practice may be superseded by an "adaptive model;" that is, instruction will be modeled on the characteristics of each student. (3) Competence develops in the student as he learns overt and covert responses that change from simple, unitary responses to large response organizations and strategies and as he learns to respond in appropriate context. (4) The usual measures of learning progress are concerned with the frequency of correct responses, errors in relation to some performance standards, and the speed of performance. Further attempts need to be made to measure transfer of knowledge, problem solving, and self-direction. References are appended. (RF)

UNIVERSITY OF PITTSBURGH · LEARNING R & D CENTER

WORKING PAPER 60

THE PSYCHOLOGY OF LEARNING AND INSTRUCTIONAL TECHNOLOGY

ROBERT GLASER

ED 047530

IRL 800W3

[redacted]

[redacted]

Learning Research and Development Center

University of Pittsburgh

1970

Published by the Learning Research and Development Center supported in part as a research and development center by funds from the United States Office of Education, Department of Health, Education, and Welfare. The opinions expressed in this publication do not necessarily reflect the position or policy of the Office of Education and no official endorsement by the Office of Education should be inferred.

THE PSYCHOLOGY OF LEARNING AND INSTRUCTIONAL TECHNOLOGY[1]

Robert Glaser
Learning Research and Development Center
University of Pittsburgh

The recent history of the psychology of learning displays an accrete progress toward contact between scientific endeavors and technological development.] In the 1920's and '30's, E. L. Thorndike showed exemplary concern for the applications of psychology for "educational science." In addition to his laboratory experimentation, Thorndike wrote extensively on educational psychology and the psychology of school subjects. Concurrent with and following Thorndike, a number of experimentally trained psychologists worked on educational problems. After this time, the psychology of learning entered a period of detachment and focused practically all of its attention on its growth as a theoretical-experimental scientific discipline. (See the reviews by Melton, 1941, and Estes, 1960 in the Encyclopedia of Educational Research.) However, beginning in the late 1950's, in a large extent catalyzed by Skinner and Bruner, experimental psychologists have turned their thinking and enterprises to the analysis and investigation of the educational, instructional process. At the present time, an instructional technology based upon an underlying science of learning is emerging. (In 1963, for the first time, the Annual Review of Psychology included a chapter on "Instructional Psychology.") Technology, of course, in the above sense, does not necessarily mean hardware and instrumentation, but rather an applied discipline like medicine or engineering. The techniques and procedures used by the practitioners of these technological disciplines develop out of findings in their underlying sciences, and also develop because these technologies sometime inform science of their needs. The purpose of this paper is to show how instructional technology has generated problems for the psychology of learning, problems that psychologists might not have taken on (or taken on with less vigor) if instructional psychology had not forced the

---

[1]Written while the author was a Fellow at the Center for Advanced Study in the Behavioral Sciences in Stanford, California, 1969-70.

learner. The point is illustrated by discussing four general questions: What is learned in a particular subject matter, who learns it, how does competence develop, and how is learning assessed and optimized?

What Are the Units of Subject Matter Learning?

A body of knowledge consists of information and of processes. Information includes data, facts, concepts, and rules; processes refer to the cognitive abilities and intellectual skills by which this information is manipulated and transformed for the purposes of acquiring new knowledge and carrying out intellectual performances. From the point of view of instructional theory and practice, the presence of competence is inferred by reference to the behavior of an individual. Thus a student possesses certain information is inferred by behavior that is taken to indicate this state of affairs. A student knows certain principles of physics because he can describe them, identify their applications, and recall and use them where appropriate. Possession of the "ability to read" is inferred by behavior present in the student which distinguishes him from a student who does not display such a behavioral repertoire. The presumption of a knowledge domain determines the specific character of a student's behavior and, hence, determines the behavior involved in acquiring the information and abilities involved. The content of a body of knowledge, i.e., the ways in which the information is structured and can be processed, must be analyzed, to some extent, before the conditions involved in the acquisition of this knowledge can be studied and implemented. As a consequence of this, an increasingly prominent feature of the psychology of learning, and attempts to apply it, to the analysis and classification of the behavior to be learned (Bruner, 1964; Gagne, 1962, 1970; Glaser, 1962; Gerlach, 1963, 1967; Gelman, 1964; Miller, 1962).

A prominent technique for the analysis of structures of knowledge has been presented by Gagne (1962). Given a task or instructional objective that must be learned, the technique entails identifying prerequisite skills and knowledge that the learner must command before he can successfully learn a new task so that a hierarchy of competence is identified. This analysis begins with a desired instructional objective, stated in terms of student behavior, and asks in effect, "to perform this behavior, what prerequisite

or competent behavior(s) must the learner be able to perform?" For each behavior identified, the same question is asked, thus generating a hierarchy of behaviors based on identifiable prerequisites. The analysis can begin at any level and postulates a sequence of learning. The importance of this backward analytical procedure for instruction is that it provides a method for identifying critical prior behaviors, behaviors which specialize transfer to new learning and whose absence may be significant impediments to future learning.

In practical applications, a hierarchical task analysis can stop when the behaviors identified are the ones that the instructional designer believes can be safely assumed to exist in the student population. Analysis of this kind attempts to provide an ordered set of tasks for inclusion in an instructional sequence. The basic contention is implied that an objective is taught so the learner will have met the prerequisites which facilitate learning and transfer to the main objective. These prerequisite learnings can be achieved in a variety of ways; some individuals can learn them one at a time, and others learn a number of them apparently in larger steps. The instructional process is optimized by continuous identification of the furthest skill along the hierarchy that a student can perform at any moment; or if a student is unsuccessful in performing a particular task objective, by determining the most immediate subobjective at which he is successful. These hierarchies indicate transfer relationships between the elements of increasing knowledge or task competence, and make explicit what behaviors are to be observed and tested for. Techniques are being developed for the generation and validation of learning hierarchies (Resnick & Wang, 1969; Resnick, Wang, & Kaplan, 1973). Psychometric scaling procedures and studies of transfer are being used to analyze the results. These results lead to the redesign of the sequences so that there is a greater match between hierarchical components and transfer of training. These procedures for analysis of what is to be learned generate structures around which instruction can be designed and learning take place.

The relationships between units of learning establish the subject matter structures that are learned, e.g., concepts, rules, principles, and strategies. With increasing knowledge and with increasing maturity of the learner, these

units of behavior become progressively larger. As certain phases in the acquisition of knowledge, a structure can become a unit of higher structure. For example, consider the progression of phases in a child learning to read. Assuming that the child has learned to speak, the first phase in the process is the discrimination of graphic symbols (printed letters). In the second phase, these discriminated objects are encoded or mapped into language so that spelling-to-sound (grapheme-phoneme) correspondences are acquired. At this point, relationships are established between the discriminated symbols and speech units. In later phases, the student learns to read not letter-by-letter, but by words and paragraphs, and the previously learned units and structures become part of higher-order structures.

In general, the objects and events that comprise the units and structures in the learning of young children are distinctive features, such as specific properties of letters, pictures, numbers, and speech sounds. Individuals learn to discriminate and attend to such specific features. They also learn certain regularities or invariances such as the frequently occurring position of letters in a particular language, frequently occurring patterns of speech, regularities of grammatical syntax, and mathematical relations such as equality and transitivity (Gibson, 1969). In large part, such structures determine or form the basis of the content of a subject matter learning that is manifested in competent subject matter behavior, and psychological research in instruction has as a basic requirement the identification of the units and structures involved in subject matter performance (Gagné & Gephart, 1968; Gibson, 1965). In addition to analyzing the structures of advanced knowledge, one must also determine those units and structures which serve optimally to facilitate learning for the novice (Brunner, 1964). This means that a technology of instruction must specify the ways in which a body of knowledge can be organized so that it can be most readily grasped by the learner as he progresses to advanced competence.

How Do Instructional Conditions Interact with the Characteristics of a Learner?

Detailed diagnosis of the initial state with which a learner comes into a particular instructional situation is necessary to further his education. In the early stages of instruction, teaching procedures adapt to the findings

of this initial assessment; later in learning, instructional conditions are adaptive to the achievement and style of the learner. In this regard, an important distinction between assessment and diagnosis must be noted: Traditional assessment practices have assumed essentially a "selection model" of instruction in which the aptitudes of a student are assessed and used to predict the student's success in a relatively uniform instructional environment for all students. In contrast, a present concern in educational psychology is to establish different conditions and procedures for learning, depending upon the initial state and progress of the learner. In this sense, present instructional psychology seeks to provide "an adaptive model" for instruction in that on the basis of assessment of an individual's characteristics, instructional conditions can be provided appropriate to the student's capabilities; in this way, different students can reach the same instructional outcomes through various learning paths.

A discussion necessary to take for this purpose has been pointed to by Cronbach (1957, 1967), and by Cronbach and Gleser (1965). These authors suggest a departure from the standard practices of test theory based upon the basic data of correlations between aptitude tests given at the beginning of a course of instruction and criterion variables measuring instructional outcomes. The new direction suggested is to move toward decision-making procedures based upon relationships between the existing behavior of a learner and the variables manipulated in instruction. Rather than employing measures of existing behavior which select individuals who have a high probability of being successful in an available instructional system, the model suggested is one in which measures are taken on the basis of which a decision can be made as to what instructional environment an individual should select in order to optimize the attainment of learning outcomes.

The implication of the adaptive model is that the relationship between measures of existing behavior and instructional method are not very useful unless these measures and instructional method interact. This means that if we have a measure of existing behavior, say, an aptitude measure, and two different instructional methods, and if the aptitude measure predicts success equally well with both methods, then it has no value in deciding which method to suggest to the student. In order to make a decision about a particular

student, with respect to what method he should consider, relationships between aptitudes and treatments are required which predict differential success with alternate methods. For the most part, measures of general aptitude and general intelligence measures are likely to be not the most useful bases for differentiating and adapting instruction because they correlate with success in most instructional methods. As a result of this state of affairs, psychologists are at present very active in the investigation of the interaction between aptitude measures and learning variables. However, the general reviews and analyses of the field of aptitude-method interactions reported by Bracht and Glass (1968), and Cronbach and Snow (1969) show a discouraging lack of interactions between traditional aptitude measures and learning variables. A further attempt to analyze the reasons for this has been presented elsewhere (Glaser, 1970a).

One direction which may provide some leads for the study of the interaction between instructional conditions and learner characteristics has been indicated in a study by Fleishman (1965, 1967). In the learning of psychomotor skills, Fleishman compared the contributions of the various abilities needed at the beginning of learning to performance scores on successive learning trials during practice. He showed that the particular combinations of abilities contributing to performance change as practice continues, and that the different abilities existing prior to entering a learning task influence learning at different learning stages. The implication is that individuals with different patterns of abilities require different learning experiences at different stages of learning. In the area of verbal learning, Jensen (1964, 1967, 1968) has suggested certain aspects of human performance that appear to interact with the learning of verbal tasks. In general, the instructional conditions that appear to be adaptive to learner characteristics are conditions related to the processes required for task performance encountered in the course of learning.

What are the Behaviors That Differentiate the Novice from the Competent Performer in a Subject Matter?

In attaining subject matter knowledge and intellectual skill, the learner proceeds through a sensitive and then an relative sequence; he

learner is to be a good reader, a competent mathematician, a deep thinker, a quick learner, a creative person, an inspiring individual, etc. These outcomes are learned according to criteria of expertise established by the school and the community; more specifically by subject matter requirements, peer group expectations, and the general social and professional criteria for what distinguishes low, average, and high levels of competence. The educational and social community adjusts its expectations to the competence level of the learners as that initially achieved and partially corrects performances are acceptable whereas later they are not; a young child or a novice is frequently rewarded for active understanding behavior but an competence grows, his performance is accepted as only if it occurs in the presence of an appropriate audience or in an appropriate context. It is the process of going from ignorance to competence, from novice to expert, that establishes a useful map of learning at the processes and characteristics of instruction. Four general properties of behavior appear to distinguish the performance of the beginner from the behavior of the expert. These are the following:

(1) The learner learns rules and covers responses that change from simple, solitary responses to large response organizations and strategies. The behavior of the novice is relatively simple, in the sense that the units of performance are small, the subject matter stimuli are not complex, the responses to these stimuli frequently involve simple matching and simple discriminations, and there is not much that appears to intervene between the subject matter content and the response. The novice's initial responses are quite variable and crude; however, as the instructor intervenes successively more rigorous standards, performance accuracy increases. Responses become more precise; they are accomplished within finer tolerances; they are less consistently performed and require little external prompting. A student of music, for example, increasingly is able to maintain a precise tempo; a mathematics student solves his problems with increasing speed and accuracy; and his geometric proofs become more elegant.

As competence grows, performance involves the integration of many responses. Performance frequently involves long chains of activity which appear to be guided by certain overall strategies and rules. Component

performance also appears to involve an adaptive use of these strategies and rules so that they are selectively used, creatively rearranged, and tentatively tested.

(2) The learner learns to respond in appropriate context. In a sense, the stimuli of the subject matter and the problem situations in which they occur "appear to exert control" over the behavior of the learner. For the beginner, the elements of the subject matter, e.g., numbers, words, formulas, concepts, and principles, may evoke behaviors which are not especially appropriate for these stimuli. Competence is displayed in the presence of subject matter contexts, to which the student responds with appropriately skillful behavior; a good editor uses words with subtle appreciation of their nuances of meaning, as does a good scientist when he uses his technical vocabulary. The more readily a stimulus context sets the occasion for the occurrence of appropriate behavior, the greater the degree to which mastery of the subject matter is manifested. In this sense, the expert is controlled by the distinctions, concepts, rules, and in general, by the discipline of his subject matter.

Specific and literal stimuli control the behavior of the beginner. As competence grows, specific stimuli become members of large classes of events so that the learner responds and generalizes to what is important among all the instances of a class. A particular instance may represent an example of a particular concept or general rule and be responded to as such; the presence of a particular conceptual structure must be detected when it is embedded in a complex context so that the complexity can be handled in a meaningful way. The music student detects the presence of certain forms of musical construction; the student of mathematics decides whether the problem at hand requires multiplication or division or the use of a particular formula for solution. Much of what occurs in subject matter learning involves responding to familiar stimuli in new contexts.

(3) The behavior of a novice is characterized by much less implicit mediation and information-processing between stimulus and response than is the behavior of an expert. While the novice in a subject matter may bring information from other subjects, he is characterized by having relatively few pertinent subject matter concepts with which to process subject matter

inputs. Increasing competence involves the development and establishment of sequences of behavior which involve explicit mediational responses and implicit information-processing procedures. At the beginning of instruction, each step in a procedure may need to be made explicit and overt; as competence grows, much of this behavior becomes internalized so that minimal external contexts can generate complex responses. The increased internalization of behavior involves increased mediation and transformation between stimulus and response. Cues for performance may be internally generated on the basis of minimal external cues; and events contingent upon a response may be supplied by the learner himself as a form of self-reinforcement (Bandura, 1971).

While the expert is less dependent than the beginner upon all the details and external supports in a situation, the expert is nevertheless highly responsive to the requirements of subject matter details, e.g., a well proportioned painting, an elegant solution for a theorem, a quick diagnosis of a symptom, and a skillful legal defense. Early in learning, explicit information and feedback need to be provided to the learner about the appropriateness or correctness of his responses. As competence grows, the student becomes increasingly able to discriminate and to establish standards for appropriate behavior; as an expert, he is now in a position to observe his own behavior and judge it in terms of what he recognizes to be a most appropriate or especially skillful response.

(4) Novice and expert are differentiated on the dimension of autonomy and independence. A beginner, for the most part, follows the instruction of his teacher or his textbooks rather strictly. He performs "according to the book," and keeps within the rules of the discipline because he is still in the process of mastering them. However, as he moves from crude responses to precise ones, from the requirements of unique instances to response classes, and from short response sequences with minimal mediation to more elaborate processing, the learner becomes increasingly free of subject matter constraints. This is akin to saying that once an expert has acquired mastery of the rules of his subject matter, he is now free to manipulate these rules in creative ways. And, since he internalizes these rules, he is less dependent on the immediate constraints of a problem situation and can generate behavior with seeming independence from external inputs and can

perform for long periods of time largely as a result of his own performance.

In summary, a model, then, of the changes that take place as an individual progresses from ignorance to competence involves the following: (1) the responses of the learner move from variable, awkward, and crude, to consistent, relatively fast, and precise. Responses develop from single unitary acts into large response integrations and overall strategies. (2) Subject matter stimuli change from specific instances to members of response classes (concept classes), and the invariants of these classes become the major stimulus events. Stimulus contexts change from simple ones with a great deal of clarity to complex patterns in which relevant aspects must be distinguished from irrelevant, and information must be abstracted from a context of events which are not all appropriate. (3) Behavior becomes increasingly symbolic and covert in the form of mediational responses and information-manipulating processes. The learner responds increasingly to internal representations of an event, to internalized standards, and to internalized strategies for thinking and problem solving. (4) The behavior of the expert becomes increasingly self-sustaining, increasingly masterful in terms of his skillful employment of the rules when they are applicable and his subtle bending of the rules in appropriate situations. Increasing reliance is placed on one's own ability to generate the events by which one learns and the criteria by which performance is judged and valued.

The process of instruction is concerned with implementing this growth from ignorance to competence, and the characteristics of the course of this growth determine the design of an instructional environment. As the learner interacts with this environment, certain lawful psychological processes influence the way in which this interchange occurs (e.g., Gagné, 1970; Glaser, 1971; Hilgard, 1964; Hilgard & Bower, 1966; Skinner, 1968). The conditions provided for instruction are determined, as has been indicated, by the properties of the behavior to be learned, the characteristics of the learner, and the nature of the growth of subject matter competence. The particular properties of the competent behavior acquired depend upon the details of the instructional environment that is provided in an educational setting, such as teacher practices, textbook design, teaching machines and instructional materials, peer-student interactions, school-community interaction, and the learning skills of the student himself.

How is Performance Assessed and Utilized for Optimizing Learning Outcomes?

With knowledge of learner characteristics and with alternate instructional procedures available, adaptation is made to the student's performance, i.e., his mastery of prerequisites, rate of learning, requirements for amount of practice, degree of necessary structure and prompting, scheduling of reinforcement, etc. Different individuals are assigned to (or the student may assign himself to) different instructional conditions. Initial placement decisions reflect only initial assignment and are corrected by further assignments as learning proceeds, so that allocation to instructional procedures becomes a multistage decision process which defines an individual instructional path.

As a student proceeds to learn, his performance is assessed at appropriate intervals, and measures of this performance are summarized and indexed. The kinds of measures of learning progress one usually obtains, and on which instructional decisions are made, consist of information (frequently test scores) which measures the frequency of correct responses, errors in relation to some performance standards, and the speed of performance. The use of measures of transfer and generalization is particularly to be encouraged; and perhaps this is done, to some extent, when one selects a set of test items which are derived from the same universe of subject matter content but are not the same sample as was used in initial learning. Of special interest are measures that are being suggested by experimental work on learning; these are measures which can be obtained in the course of learning and may be predictive of future learning requirements. Work along these lines has been mentioned elsewhere (Glaser, 1970b).

An adaptive instructional process employs a reiterative pattern of assessment and instructional prescription where decisions are made sequentially, and decisions made early in the process affect decisions made subsequently. The task of instruction is to prescribe the most effective sequence of learner-environment interactions. Problems of this kind in other fields of endeavor have been tackled by optimization procedures (e.g., Wilde & Beightler, 1967). Optimization procedures involve methods of making decisions by selecting measures of effectiveness and determining the best solution according to those criteria, taking account of appropriate situational

remediate. Green and Atkinson (1968) have outlined how an instructional model would operate along these lines. The optimization problem of major concern is finding a decision procedure (to be implemented by the student, teacher, and/or a teaching device) for deciding which instructional alternatives to present at each stage, given the instructional alternatives available, the set of possible student responses to the previous lesson unit, and specification of the criteria to be optimized for the judgment of competence. This decision procedure defines an instructional strategy.

The design of an adaptive approach to instruction requires at least two essential tasks: The first requirement is for experimental studies of learning to place emphasis on discovering the relationship between individual differences and learning variables. Fortunately, there is a growing commitment in learning theory to the individual case--recognized but not incorporated to any extent by Hull, certainly urged upon us by Skinner and associates, and recognized in the recent information-processing, computer simulation models of human behavior. There seems little doubt that one major test of the adequacy of competing learning theories will be the extent to which they incorporate parameters which account for individual differences.

The second task refers to the fact that criterion measures of what is to be optimized become critical. If individualizing the instructional process permits instruction to become precise enough, a good job can be done to maximize some gains and minimize others, but some criteria may be minimized inadvertently unless the presence of the latter is desired, analyzed, and assessed. Extensive work is going on in measurement theory and techniques as related to the instructional process (Ebermath, 1969; Cronbach, 1963; Glaser & Nitko, 1971). In part, this work involves techniques for the development of criterion-referenced measures of achievement in contrast to the more commonly used norm-referenced measures (Ebel, 1962; Flanagan, 1951; Glaser, 1963; Popham & Husek, 1969). Criterion-referenced measures are tests that are constructed to yield measurements that are directly interpretable in terms of specified performance standards rather than relative standards such as percentile scores or normal-curve standard scores. In addition, serious attempts need to be made to measure what has heretofore been so difficult--those aspects of learning and knowledge that are basic to an

individual's capability for continuous growth and development, including transfer of knowledge to new situations, problem solving, and self-direction.

References

Bandura, A. Vicarious and self-reinforcement processes. In R. Glaser (Ed.), The nature of reinforcement. Columbus, O.: Charles Merrill, 1971. In press.

Bormuth, J. R. On achievement test item theory. Chicago: University of Chicago Press, 1969.

Brooks, G. W., & Glass, G. V. The external validity of experiments. American Educational Research Journal, 1969, 3, 437-474.

Brown, J. S. Some theorems on instruction illustrated with reference to maintenance. In Theories of learning and instruction, Sixty-third Yearbook, Part I, National Society for the Study of Education. Chicago: University of Chicago Press, 1964. Pp. 306-335.

Cronbach, L. J. The two disciplines of scientific psychology. American Psychologist, 1957, 12, 671-684.

Cronbach, L. J. Course improvement through evaluation. Teacher's College Record, 1963, 64, 672-683.

Cronbach, L. J. How can instruction be adapted to individual differences? In R. Gagne (Ed.), Learning and individual differences. Columbus, O.: Charles Merrill, 1967. Pp. 23-39.

Cronbach, L. J. & Gleser, G. C. Psychological tests and personnel decisions. (2nd ed.) Urbana, Ill.: University of Illinois Press, 1965.

Cronbach, L. J., & Snow, R. E. Individual differences in learning ability as a function of instructional variables. Final report, Stanford University, School of Education, March 1969.

Ebel, R. L. Content-standard test scores. Educational and Psychological Measurement, 1962, 22, 15-25.

Flanagan, J. C. Units, scores, and norms. In E. F. Lindquist (Ed.), Educational measurement. Washington, D. C.: American Council on Education, 1951. Pp. 695-763.

Fleishman, E. A. The description and prediction of perceptual-motor skill learning. In R. Glaser (Ed.), Training research and education. New York: Wiley, 1962. Pp. 137-175.

Fleishman, E. A. Individual differences in motor learning. In R. Gagne (Ed.), Learning and individual differences. Columbus, O.: Charles Merrill, 1967. Pp. 165-191.

Gagne, R. M. The acquisition of knowledge. Psychological Review, 1962, 69, 355-365.

Gagne, R. M. The analysis of instructional objectives for the design of instruction. In R. Glaser (Ed.), Teaching machines and programmed learning. Vol. II. Data and directions. Washington, D. C.: National Education Association, 1965. Pp. 21-43.

Gagné, R. M. The conditions of learning. (2nd ed.) New York: Holt, Rinehart, & Winston, 1970.

Gagné, R. M., & Gephart, W. J. (Eds.) Learning research and school subjects. Itasca, Ill.: F. E. Peacock, 1968.

Gibson, E. J. Learning to read. Science, 1965, 148, 1066-1072.

Gibson, E. J. Principles of perceptual learning and development. New York: Appleton-Century-Crofts, 1969.

Glaser, R. Some research problems in automated instruction: instructional objectives and subject-matter structure. In J. E. Coulson (Ed.), Programmed learning and computer-based instruction. New York: Wiley, 1962. Pp. 67-81.

Glaser, R. Instructional technology and the measurement of learning outcomes: Some questions. American Psychologist, 1963, 18, 519-521.

Glaser, R. (Ed.) Teaching machines and programmed learning. Vol. II. Data and directions. Washington, D. C.: National Education Association, 1965.

Glaser, R. Individual differences in learning. In Individualized curriculum and instruction -- Proceedings of the Third Invitational Conference on Elementary Education. Edmonton: University of Alberta, 1970, in press. (a)

Glaser, R. Psychological questions in the development of computer-assisted instruction. In R. Holtzman (Ed.), Computer-assisted instruction, testing, and guidance. New York: Harper & Row, 1970, in press. (b)

Glaser, R. (Ed.) The nature of reinforcement. Columbus, O.: Charles Merrill, 1971, in press.

Glaser, R., & Nitko, A. J. Measurement in learning and instruction. In R. L. Thorndike (Ed.), Educational measurement. Washington, D. C.: American Council on Education, 1970, in press.

Green, D. J., & Atkinson, R. C. Models for optimizing the learning process. Psychological Bulletin, 1964, 66, 309-320.

Gulliksen, H. H. (Ed.) Theories of learning and instruction. Sixty-third Yearbook, Part I, NSSE. Chicago: University of Chicago Press, 1964.

Gulliksen, H. H., & Moser, C. H. Theories of learning. (3rd ed.) New York: Appleton-Century-Crofts, 1964.

Jensen, A. R. Individual differences in concept learning. In H. J. Klausmeier & C. W. Harris (Eds.), Analysis of concept learning. New York: Academic Press, 1966. Pp. 139-154.

Jensen, A. R. Variation of individual differences in learning. In R. Gagné (Ed.), Learning and individual differences. Columbus, O.: Charles Merrill, 1967. Pp. 117-148.

Jensen, A. R. Social class and verbal learning. In M. Deutsch, et al. (Eds.), Social class, race, and psychological development. New York: Holt, Rinehart, & Winston, 1968. Pp. 115-174.

Gagné, R. Science education and behavioral technology. In R. Glaser (Ed.), Teaching machines and programmed learning. Vol. II. Data and directions. Washington, D. C.: National Education Association, 1965. Pp. 441-447.

Gagné, R. Behavioral analysis and instructional sequencing. In P. C. Lange (Ed.), Programmed instruction. Sixty-sixth Yearbook, Part II. NSSE. Chicago: University of Chicago Press, 1967. Pp. 81-103.

Gelcom, A. W. (Ed.) Categories of human learning. New York: Academic Press, 1964.

Miller, R. B. Analysis and specification of behavior for training. In R. Glaser (Ed.), Training research and education. New York: Wiley, 1962. Pp. 31-62.

Popham, W. J., & Husek, T. R. Implications of criterion-referenced measurement. Journal of Educational Measurement, 1969, 6, 1-9.

Resnick, L. B., & Wang, M. C. Approaches to the validation of learning hierarchies. Paper presented at the 10th Annual Western Regional Conference on Testing Problems, San Francisco, May 1969.

Resnick, L. B., Wang, M. C., & Kaplan, J. A hierarchically sequenced introductory mathematics curriculum. Pittsburgh: Learning Research and Development Center, University of Pittsburgh, 1970.

Skinner, B. F. The technology of teaching. New York: Appleton-Century-Crofts, 1968.

Wilde, D. J., & Beightler, C. S. Foundations of optimization. Englewood Cliffs, N. J.: Prentice-Hall, 1967.